Transitioning from Hoc to Python as the Tool for Computational Modeling of Neurons, Networks, and Deep Brain Stimulation

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ABSTRACT

Quantitative methods of analysis have become increasingly popular in biology – in particular computational modeling. It has become an important research tool in understanding processes within the brain given its dynamic and stochastic tendencies. Computational modeling has allowed for the development of models that can show how the interplay among ion channels can result in emergent spike activity and how external perturbations can modulate this activity. In this study, we **developed a framework for modeling neurons using the programming language Python** to write a library to interface with an established neuron simulation environment, NEURON. This library incorporated automated routines for the analysis of neuronal spike rate, spike pattern, and per-stimulus time histograms. The library was **tested on a model of the spontaneously active neuron**, Globus Pallidus internus (GPi), being **perturbed by an extracellular electrical stimulation** at a high frequency – a clinical therapy known as **Deep Brain Stimulation** (DBS). This new modeling framework will facilitate future development and expansion of Python-based scripts and programs for interfacing with NEURON and automating the analyses of the simulations run. The framework will also allow for the **development of more efficient algorithms for identifying specifically which neuronal pathways within the brain correspond to which DBS parameters**.

INTRODUCTION

What is Neuron?

• NEURON is a simulation environment that builds and uses computational models of neurons and networks of neurons
(Carnevale & Hines, 2013)

Why Python?

• Active development from within scientific community
• Hoc functionality has been already been implemented
(Carnevale & Hines, 2013)

REFERENCES

1. Carnevale, N. T., & Hines, M. L. (2013). NEURON. Retrieved 22, 2013, from http://www.neuron.yale.edu/neuron/
2. Johnson, M. D., & McIntyre, C. C. (2008). Quantifying the Neural Elements Activated and Inhibited by Globus Pallidus Deep Brain Stimulation. *Journal of Neurophysiology, 100*(November 2008), 15.

Hypothesis

By using Python, one may be able to draw from the strengths of both Hoc and Python languages to create more powerful scripts and programs.

METHODS

• Use histology to make models of tissue and neuron morphology

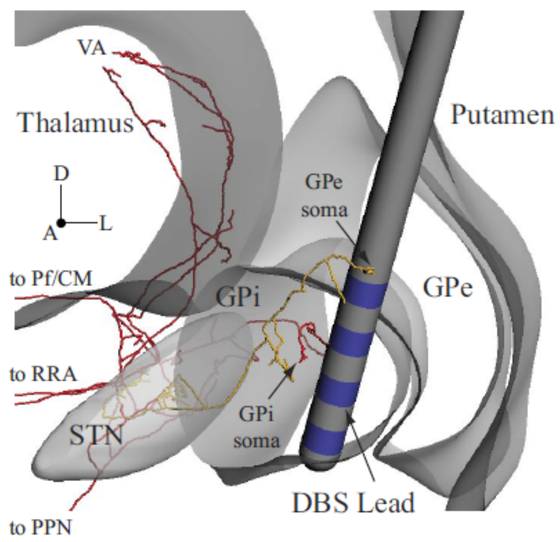

Figure 1: Atlas-Based DBS Model of region containing GPi with DBS lead. (Johnson & McIntyre, 2008)

• Find parameter solutions
• Simulation Action Potential (AP) propagation

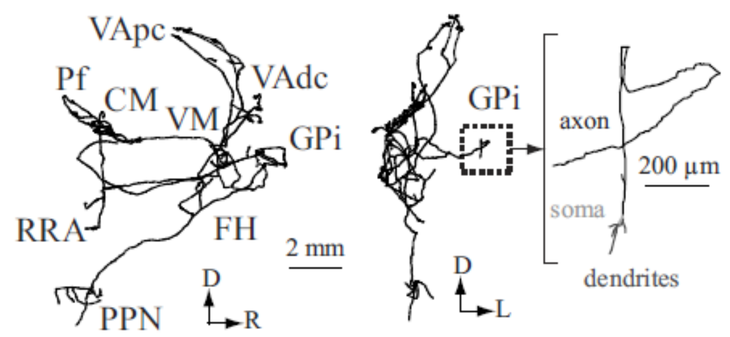

Figure 2 : Anatomical reconstruction of a GPi projection neuron. (Johnson & McIntyre, 2008)

• Write library for simulation previously run through Hoc
• Incorporate automated analysis of simulation

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Comparison of Simulation Approaches

(A) (B)

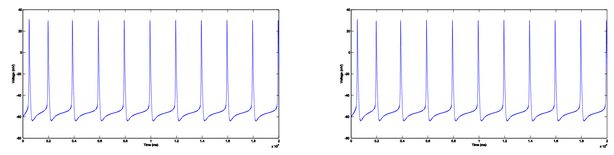

Figure 3: (A) Plot of voltage results from Hoc script. (B) Plot of voltage results from Python library.

Enabling Python Library: Peristimulus Time Histograms

• Incorporated dynamic Histogram creator

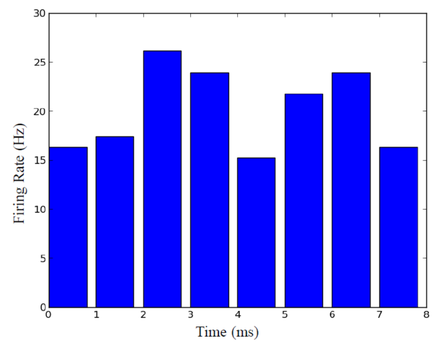

Figure 4: (A) Histogram of GPi without DBS (B) Histogram of GPi with DBS

• Not all hoc functionality available within python
• Easy to replicate with "Hoc fields"
• Wasn't able to replicate procedure functionality from Hoc

Python (s)	Hoc (s)
0.116998910904	0.11999989

Figure 5: Comparison of run-times for Python library and Hoc Script.

CONCLUSION

• Python is a better language to use for simulations and certain automated analyses
• Python will allow for on-line analysis

Future Directions

• Incorporate "pointer-like" functionality from C++ to create circular dependencies between "Hoc fields" and "Python fields"

• Automate the optimization of model parameters to fit experimental data

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